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ROGER BACON AND EXPERIMENTAL METHOD IN THE MIDDLE AGES.

THE year 1914 marks approximately the seventh centennial of the birth of Roger Bacon, and offers opportunity for a reconsideration of his place in thirteenth century thought and of his relation to modern science. Two hundred years ago, before Jebb had edited the *Opus Maius* in 1733, Roger Bacon was unappreciated and unknown. Today many will incline to celebrate his anniversary as that of the first rebel against mediæval scholasticism and the first prophet of modern science. They may feel that such recognition is the more due to his memory because they believe him to have been a prophet without honor and persecuted in his own age, or because they believe that in later times Francis Bacon received the praise that was Roger's due. They will set Roger's four causes of human error against Francis's idols; they will point to Roger's urging the study of Greek, Arabic, and Hebrew as well as Latin, and to his sharp criticism of the translations of Aristotle in vogue in his day, to his investigations in optics, to his insistence upon the importance of the mathematical method, whose value Francis scarcely realized; but above all they will remember Roger's criticism of scholastic methods, of reliance on authority, and his advocacy of experimental method. It is of this last point, long regarded as the brightest gem in Roger's crown, that the present article will treat, inquiring what Bacon's discussion of 'experimental science' really amounts to, whether his conception was a novel one or the common property of his age, and finally what the actual status of experimentation was at that time.

But before attacking this particular problem it will be well to give some idea of recent study of Bacon and the progress of opinion concerning him, especially since doing this will pave the way for our argument. Much attention has been given to Bacon since the editing in 1859 by Brewer of a number of his writings hitherto unpublished,[1] and the almost simultaneous appearance in 1861 of Émile Charles's *Roger Bacon; sa vie, ses ouvrages, ses doctrines.* Unfortunately Charles wrote without knowledge of Brewer's labors, and it must be added that several writers on Bacon since have failed to keep abreast with the latest research in their field. These works by Brewer and Charles educed a number of minor essays and studies in the following decades.[2] Then a new impetus to the study of Bacon was given in 1897 when the *Opus Maius*, previously accessible only in Jebb's rare and incomplete edition, was re-edited by Bridges.[3] In the same year Father Gasquet published a new fragment which he regarded as an introduction to the *Opus Maius*.[4] In 1902 Nolan and Hirsch edited Bacon's Greek Grammar. Then in 1909 Professor Duhem gave to the world a newly discovered fragment of the *Opus Tertium:* in 1911 the British Society of Franciscan Studies printed the *Compendium Studii Theologiæ*, and, in 1912, more of the *Opus Tertium*.[5] Meanwhile Robert Steele, who in 1905 had edited a fragment of Bacon's Metaphysics, since 1912 has been producing the *Communia Naturalium.*

As Bacon's works have thus become more generally known and as standards of historical criticism have grown more strict, his life, doctrines, and point of view or personal equation have been more carefully examined and analyzed, and much legend and exaggeration have been exposed, although still repeated in some quarters. Indeed, the very writer who rejects some one legend may hold fast to the old view of Bacon in all other respects.

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[1] Fr. Rogeri Bacon *Opera quaedam hactenus inedita.* Ed. J. S. Brewer, London, 1859; Vol. 15 of *Rerum Britannicarum medii aevi scriptores,* (published under the direction of the Master of the Rolls and usually spoken of as "The Rolls Series"). This work will hereafter be cited as *Brewer.*

[2] For bibliography of these and later works on Bacon see the article on Roger Bacon in the *Catholic Encyclopedia,* and "The Seventh Centenary of Roger Bacon (1214–1914)," by Fr. Paschal Robinson in *The Catholic University Bulletin,* Vol. XX, pp. 3–9 (Jan., 1914).

[3] The *Opus Maius* of Roger Bacon. Ed. J. H. Bridges, Vols. I and II, Oxford, 1897; Vol. III (correcting numerous errors in I and II), 1900. This work will be hereafter cited as *Bridges.*

[4] *English Historical Review,* XII, 494–517. This will be cited as *Gasquet.*

[5] *Part of the Opus tertium of Roger Bacon.* Ed. A. G. Little, Aberdeen, 1912. This will be cited as *Little.* It includes Duhem's fragment.

There is, therefore, the more reason for a brief collective review of this criticism which hitherto has been somewhat piecemeal and fragmentary.

For one thing, it is admitted by many that Bacon did not anticipate modern inventions by actual discoveries. As far back as 1864 *The Westminster Review* said: "It can easily be shown that of the things which Bacon is asserted to have invented, several were perfectly well known before his time, and the rest are nowhere described in his works."[6] He mentions spectacles and explosives but does not claim them as his own discoveries; he dreamed of future marvels of science but he worked none of them out in detail. Perhaps he thought that he could, but then, he thought that he could make gold artificially.

Secondly, Bacon cannot be proved a martyr to science, nor have we any evidence that his contemporaries hated him and that the church persecuted him for his scientific studies. On the contrary, his best works were produced at the command of the pope,[7] and one of their chief aims is to induce the church to enlist science in its service and to profit by scientific discoveries. Abbé Feret has shown how through the nineteenth century successive historians, including even Charles, kept adding to the story of Bacon's persecution by the Franciscans, without giving any references to the sources for details which they elaborated from their imaginations.[8] The legend that he was imprisoned from 1257 to 1267 rests simply on unwarranted inference from his own statements to the pope,[9]—statements which really only show that in recent years he has not won the fame which he thinks his due, that he is jealous of his more successful contemporaries, and that he is desperately anxious to secure the pope as his patron. However, an Assisi manuscript of the early fourteenth century states that in 1277, a decade after his writings to the pope, a council of his Order condemned "the doctrine of Rogerius Bacho, an English master of sacred theology, since it contained some suspected novelties, on account of which the said Roger was condemned to prison."[10] But what the novelties were we are not informed; they were probably theological rather than scientific. Some writers have assumed that they were astrological, but there was nothing 'novel' about Bacon's astrology.[11] Theories that Bacon was accused of magic are also unwarrantable inferences from his own statements. He complains that the Canon Law confuses mathematics and magic, and that philosophers are sometimes falsely accused of magic; it is thereupon assumed that what he says may happen to others did happen to himself.

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[6] Vol. 81, p. 247, in an article on "The Philosophy of Roger Bacon." At page 1 of the same volume begins an article on "The Life and Writings of Roger Bacon."

[7] For the pope's letter see *Brewer*, p. 1.

[8] P. Feret, "Les emprisonnements de Roger Bacon," *Revue des questions historiques*, Vol. 50, pp. 119–142. See also the *Catholic Encyclopedia;* whereas the last edition of the *Brittanica* preserves the old legends. For a *reductio ad absurdum* of the legend-building note, A. Parrot, *Roger Bacon et ses contemporains*, Paris, 1894. Parrot also is ignorant of Brewer's edition and regrets that the *Opus tertium* is still unprinted (p. 51).

[9] Contained mainly in the first twenty chapters of the *Opus tertium*.

In the third place, Bacon's outspoken criticism of the learning of his age is no longer unquestioningly accepted. A review in the *English Historical Review* for October 1912, "hopes that it is not an article of faith with the Society of Franciscan Studies to accept all of Roger Bacon's statements. As regards the state of knowledge among his contemporaries, his assertions are often of no greater value than the similar assertions of his distinguished namesake in a later age."[12] It is seen that his tendency to indulge in personalities and to belittle his distinguished contemporaries must be discounted. When he sneers at meritorious scholars like Albertus Magnus and William of Meerbeke,[13] one wonders how far to accept his hostile estimate of the schools at Paris, his boasts of his own superior knowledge and better methods of teaching, his professed exploitation of neglected fields in linguistics, mathematics, optics, alchemy, and experimental science. His censure of the translations of Aristotle in use at Paris loses much of its force, when we learn that he himself bases some of his views upon mistranslated passages from Aristotle,—passages which Albert and Aquinas translate as well or better than he.[14] Also we must remember that Bacon is addressing the pope and trying to interest him not only in the reform and advancement of learning but in Roger Bacon. So if, as Macaulay said, Francis Bacon seeking the truth was a very different person from Francis Bacon seeking the seals, we must remember that Roger combines both attempts at once.

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[10] *Bridges*, III, 158.

[11] P. Mandonnet, "Roger Bacon et le 'Speculum astronomiæ,'" *Revue Néo-Scolastique*, Vol. 17 (Aug., 1910), tries to prove that Bacon and not Albertus Magnus wrote the *Speculum*, that it was written in 1277, and that he was condemned on account of it; but I see many reasons (which I hope to set forth in print soon) for hesitating to accept his conclusions. Mandonnet's method of historical inference in another connection has been satirized by Ch. v. Langlois in the *Revue de Paris* for Sept. 1, 1900.

[12] "W. H. V. R." on p. 810.

[13] *Opus tertium*, Cap. 2, and *Compendium studii*, Cap. 8 (*Brewer*, p. 14 and 472).

Fourthly, the faults of Bacon's own learning, his superstition and credulity, his belief in alchemy and astrology, have been noticed, so that a recent reviewer speaks of "the usual Baconian atmosphere, in which science and superstition are happily or unhappily compounded."[15] These weaknesses are usually charged in large measure and correctly to the age in which Bacon lived; but, while some treat them as only throwing his merits into higher relief, these failings at least support Hastings Rashdall's assertion that "Bacon was more the child of his age than he imagined himself to be,"[16] and perhaps may be taken as an indication that his virtues, too, were those of his age.

Father Mandonnet, the erudite author of *Siger de Brabant et l'averroïsme latin au XIIIe siècle*, thinks that Bacon's importance has in many ways been over-estimated.[17] While Charles held that, if Bacon's scientific importance had been exaggerated, his value as a schoolman had been lost sight of, Mandonnet affirms that as a philosopher and theologian, Bacon was behind rather than in the forefront of his age. Bacon has been reproached for making philosophy and science ancillary to theology,[18] but he could scarcely do otherwise when addressing the pope and trying to induce the church to support science.

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[14] K. Werner, "Die Kosmologie und allgemeine Naturlehre des Roger Baco," *Sitzungsberichte d. ph.-hist. cl. etc.*, Wien, 1879, Band 94, p. 495.

[15] "W. H. V. R." in *English Historical Review*, Vol. 28, p. 805 (Oct., 1913).

[16] *Fratris Rogeri Bacon Compendium Studii Theologiæ.* Ed. H. Rashdall, Aberdeen, 1911, p. 3.

[17] Mandonnet, *Siger de Brabant*, Deuxième édition, 1908–1910, Vol. I, pp. 40, 244–8.

[18] See *Gasquet*, 509. Nam sum certus quod solum illud de philosophia est utile et dignum quod sapientia sacra dignatur, sicut ab ancilla, requirere; totum enim residuum stultum est et insanum. See also H. O. Taylor, *The Mediæval Mind*, II, 486.

This changing tide of opinion concerning Bacon's life and works both suggests that there may be room for further revision of our estimate of him, and provides a more correct setting for his discussion of experimental science. But to evaluate this properly we must rid ourselves of one more false assumption, namely, that mediæval learning was exclusively scholastic and theological, and that Bacon in his advocacy of natural science was "a voice crying in the wilderness." This notion still survives in writers whose estimate of Bacon is otherwise sane and critical. Thus the articles in *The Westminster Review*, quoted above against the attribution of modern inventions to Bacon, and which further state that the merit of the *Opus Maius* "lies rather in the spirit in which it was written than in the facts it records or in any merit which it may have as a scientific whole," go on to say that "Bacon preached a philosophy of which not half-a-dozen men in Europe saw the value, and of which the majority of really good men feared the results," and that "when Roger Bacon was laid in his grave the real philosophy was buried with him."[19] Such is still the impression given by otherwise excellent recent estimates of Bacon, such as those in the *Catholic Encyclopedia* and in Henry Osborn Taylor's *The Mediæval Mind*.[20]

But such an assumption is ungrounded. Most educated persons are, it is to be hoped, by this time aware that the middle ages were not 'dark ages,' that the classical revival of the 15th and 16th centuries was no new birth of civilization, and that our modern states, literatures, laws, cities, and universities had begun by the twelfth century. It should equally be realized that the rise of modern science can no more be associated with the so-called Renaissance than with the so-called Middle Ages. The scientific interests and the characteristics of works on nature in those two periods were very similar. Of course there was progress, but there was no break, they merge into each other. Galileo's telescope was the natural outgrowth of earlier investigations concerning lenses which had resulted in the use of spectacles as early as the thirteenth century. Printers of the 15th and 16th centuries found plenty of readers for the many mediæval works on nature which they published and which often ran through several editions. The narrow humanist had no more interest in natural science than the narrow schoolman. In the middle ages logic and discussion were not the only forms of intellectual exercise, though they largely displaced the rhetoric and oratory of Roman days. The collection of facts was another engrossing pursuit, as the voluminous mediæval encyclopedias testify; there was keen curiosity about the things of this world. Open a book for general reading in a vernacular language, the long French poem, *The Romance of the Rose*, and you will find there more allusions to natural science and to human history than to logic and theology. Perhaps in the early middle ages literature was almost exclusively ecclesiastical and based upon patristic authorities. But through the twelfth century the tide of secular and scientific learning was rising, until in the first part of the next century the University of Paris was powerless to prevent the study of the newly discovered books of Aristotle in natural philosophy. Aristotle, moreover, was far from being the sum and substance of mediæval science which drew from many other sources, such as Ptolemy, Pliny, Galen, and the Arabs, and which made original contributions and practical discoveries of its own. It was an age when even a superstitious book on magic and necromancy such as *Picatrix* declared that science was God's greatest gift to man, since "It always is making acquisitions and never diminishes; it ever elevates and never degenerates; it is always clear and never conceals itself."[21] And even Bacon asserts that many scientific facts and truths were now known of which Plato and Aristotle, Hippocrates and Galen had been ignorant.[22]

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[19] *Westminster Review*, Vol. 81, pp. 12, 9, and 252.

[20] Taylor's discussion of Bacon occurs in Vol. II, pp. 483–508. He goes farther than the sources justify in some of his assertions concerning Bacon's life, though he is caution itself compared to some writers.' For instance, it cannot be shown that before 1266 Roger's pursuit of learning "had been obstructed by the Order of which he was an unhappy and rebellious member"; nor that "he had evidently been forbidden to write, or spread his ideas; he had been disciplined at times with a diet of bread and water."

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[21] Lib. I, Cap. 1, of *Picatrix* as contained in Ms. XX, 20, National Library, Florence. Semper acquirit et numquam diminuit; semper elevat et numquam degenerat; semper apparet et numquam se abscondit. *Picatrix* was translated from Arabic into Spanish by order of Alfonso X. (1252–1284), and eventually was translated into Latin. There are two Mss. of it at Florence.

It would be exceeding the limits of this article to discuss further this mediæval interest in natural science, and there are already a number of books or papers dealing with that field, although undoubtedly a great deal remains to be done. Even the subject of experimentation in the middle ages has been approached, but never sufficiently discussed. Pouchet in his *Histoire des sciences naturelles au moyen âge, ou Albert le Grand et son époque considérés comme point de départ de l'école expérimentale*[23] was one of the first to point out Albertus Magnus's insistence on the necessity of experience as a criterion of truth in natural science, but his discussion goes little farther than that. Abbé Narbey's "Le moine Roger Bacon et le mouvement scientifique au XIIIe siècle"[24] is another promising title which leads to disappointment. Mr. Taylor gives a discriminating analysis and estimate of Bacon's discussion of experimental science, considered *per se*, but regards it as a unique contribution, calling it "this most original and 'advanced' product of Bacon's genius."[24a]

It has, however, been observed that there was much practical experimenting in Bacon's time among artisans and alchemists. Picavet writes on this point, "It is well known that the technical arts attained great perfection. What is less realized is that the thirteenth century marks an important epoch in the history of the experimental sciences, that Roger Bacon is not an isolated apparition or exception. There was a whole school of alchemists who performed the experiments mentioned by ancient writers and devised new ones."[25] But this article will not compare what Bacon said with what others did but only with what others said;

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[22] *Brewer*, p. 542; *De secretis operibus artis et naturæ et de nullitate magiæ*, Cap. 7.

[23] Paris, 1853.

[24] *Revue des questions historiques*, Vol. 35 (1884), pp. 115–166. Narbey is still another Frenchman who shows no acquaintance with Brewer's edition.

[24a] H. O. Taylor, *The Mediæval Mind*, II, 500.

[25] F. Picavet, *Esquisse d'une histoire générale et comparée des philosophies médiévales*, Paris, 1905, p. 224. See, too, P. E. M. Berthelot, *La chimie au moyen âge*, 1893, 3 vols.

it will confine its attention to allusions to experimental method in the writings of Bacon and his contemporaries. Many of the latter are today comparatively inaccessible and unknown, since they exist only in rare old printed editions; and the admirers of Bacon who reproach previous centuries with their neglect of Roger's works are unconscious that they are similarly neglecting a considerable group of mediæval men of science.

We have first to examine Bacon's discussion of "experimental science" (*scientia experimentalis*), to which one section of his *Opus Maius* is devoted[26] and to which he adverts more briefly in other works. He regards it as the best criterion of truth in natural science. "All sciences except this either merely employ arguments to prove their conclusions, like the purely speculative sciences, or have universal and imperfect experiences;"[27] while "It alone, in truth, has the means of finding out to perfection what can be done by nature, what by the industry of art, what by fraud"; for it alone can distinguish what is true from what is false in "incantations, conjurations, invocations, deprecations, and sacrifices."[28]

But how is one to set about experimenting? On this point Bacon is disappointing. His explanation of the rainbow, which is his longest illustration of the value of experimental science, is based merely on ordinary intelligent observation and reasoning, although he adds at the close that tests with instruments are needed and that consequently he will not assert that he has reached the full truth of the matter.[29] Elsewhere he speaks of astronomical experiments "by instruments made for this purpose," but seems to regard the unaided eyesight as sufficient for the investigation of terrestrial phenomena. Bacon has sent "over sea and to various other lands and to annual fairs, in order that I might see the things of nature with my own eyes."[30] "And those things which are not present in our locality we may know through other sages who have experienced them, just as Aristotle by authority of Alexander sent two thousand men to different regions to experience all things on the face of the earth, as Pliny testifies in his Natural History."[31] The one contemporary who most nearly fulfills Bacon's ideal of what an experimental scientist should be, does not spend his time merely in reading, attending lectures, and engaging in disputations, but "is ashamed to have some layman or old-wife or knight or rustic know facts of which he is ignorant"; hence he goes out into the world and observes the doings of common workingmen and even takes hints from the operations of witches, enchanters, and magicians.[32] Bacon even believes that valuable medicines can be discovered by observing what remedies various animals employ. It would seem that experimental method is in a low stage of its development, if it takes lessons from common human experience and from the actions of brutes. Bacon sufficiently indicates, however, that it does not consist merely of observation and casual experience, but includes purposive experimentation, and he often speaks of "experimenters." Undoubtedly he himself experimented. But the fact remains that he gives no directions concerning either the proper environment for experimenting or the proper conduct of experiments. Of laboratory equipment, of scientific instruments, of exact measurements, he has no more notion apparently than his contemporaries.

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[26] *Bridges*, II, 167–222; *Little*, 43–54.

[27] *Gasquet*, 510. . . . scientie omnes preter hanc vel utuntur argumentis tantum ad probationem conclusionum suarum, ut pure speculative scientie, vel habent experientias universales et imperfectas.

[28] *Bridges*, II, 172. Hæc ergo sola novit perfecte experiri quid potest fieri per naturam, quid per artis industriam, quid per fraudem, quid volunt et somniant carmina conjurationes invocationes deprecationes sacrificia. . . .

[29] *Ibid.*, II, 201.

Bacon says far more of the marvelous results which he expects experimental science to achieve than he does of method. Some of his dreams have been brought true by modern mechanical inventions, but in the main marvelousness rather than practicability characterizes the aims which he proposes for *scientia experimentalis.* Indeed, of the three ways in which he represents it as superior to all other sciences, while one is that it employs sure proofs rather than mere arguments, two are that by it life may be greatly lengthened, and that from it a better knowledge of the future may be gained than even from astrology.[33] Thus experimental method is especially connected with alchemy and astrology. Bacon declares that "it has been proved by certain experiments" that life can be greatly prolonged "by secret experiences,"[34] and he believes that Artephius was enabled by such methods to live for a thousand and twenty five years.[35]

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[30] *Gasquet*, 502. Unde multotiens ego misi ultra mare et ad diversas alias regiones et ad nundinas sollemnes ut ipsas res naturales oculis viderem et probarem veritatem creature per visum. . . .

[31] *Bridges*, II, 169. Et quæ non sunt præsentia in locis in quibus sumus, scimus per alios sapientes qui experti sunt. Sicut Aristoteles auctoritate Alexandri misit duo millia hominum per diversa loca mundi ut experirentur omnia quæ sunt in superficie terræ, sicut Plinius testatur in Naturalibus.

[32] *Brewer*, 46–47. Immo verecundatur si aliquis laïcus, vel vetula, vel miles, vel rusticus de rure sciat quæ ipse ignorat.

Some of his 'experiments' are as fantastic as the aims are marvelous. "A good experimenter says in the book *De regimine senum*" that the following elixir will greatly prolong life: "that which is temperate in the fourth degree, and what swims in the sea, and what grows in the air, and what is cast up by the sea, and plant of India, and what is found in the entrails of an animal of long life, and those two serpents which are the food of the inhabitants of Tyre and Aethiopia."[36] We also are told that "at Paris recently there was a sage who asked for snakes and was given one and cut it into small sections except that the skin of its belly on which it crawled remained intact; and that snake crawled as best it could to a certain herb by touching which it was instantly made whole. And the experimenter collected a herb of wonderful virtue."[37]

Credulity, in contrast to the skeptical attitude of modern science, is a characteristic of Bacon's experimental method. He declares it true that experiment disproves many false notions, but he also asserts that credulity is necessary in experimentation. "First one should be credulous until experience follows second and reason comes third. . . . At first one should believe those who have made experiments or who have faithful testimony from others who have done so, nor should one reject the truth because he is ignorant of it and because he has no argument for it."[38] Taken as a plea for an open minded attitude toward scientific investigation on the part of the ordinary man and of the ecclesiastical authorities, this utterance may be commended; but as a prescription for the scientific investigator it is dangerous. Many of Bacon's 'experiments' are copied from books, and the reproach made against the Greek Empirics that they followed tradition, applies also to him. Describing a certain marvel of nature, he exclaims, "After I beheld this, there was nothing difficult for my mind to believe, provided it had a reliable author."[39] In the midst of his discussion of experimental science we encounter the following instance of his gullibility.

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[33] *Gasquet,* 510; and *Bridges,* passim.

[34] *Bridges,* II, 205. Præterea certis experimentis probatum est, quod ista festinatio nimia est retardata pluries, et longævitas prolongata per multos annos per experientias secretas.

[35] *Ibid.,* 212.

[36] *Ibid.,* 210. Et ideo dicit experimentator bonus in libro de Regimine Senum, quod si illus quod est in quarto gradu temperatum, et quod natat in mari, et quod vegetatur in ære, et quod a mari projicitur, et planta Indiæ, et quod est in visceribus animalis longæ vitæ, et duo serpentes quæ sunt esca Tyrorum et Æthiopum, ...

[37] *Ibid.,* 208. Nam Parisius nuper fuit unus sapiens, qui serpentes quæsivit et unum accepit et scidit eum in parva frusta, nisi quod pellis ventris, super quam reperet, remansit integra, et iste serpens repebat ut poterat ad herbam quandam, cuius tactu statim sanabatur. Et experimentator collegit herbam admirandæ virtutis.

"It is certain that Æthiopian sages have come into Italy, Spain, France, England, and those Christian lands where there are good flying dragons; and, by an occult art that they possess, excite the dragons from their caves. And they have saddles and bridles ready, and they ride the dragons, and drive them at top speed through the air, in order to soften the rigidity and toughness of their flesh, just as boars, bears, and bulls are hunted with dogs and beaten with many blows before they are killed for eating. And when they have tamed the dragons in this way, they have an art of preparing their flesh . . . , which they employ against the accidents of age and prolong life and inspire the intellect beyond all estimation. For no education which man can give will bestow such wisdom as does the eating of their flesh, as we have learned without deceit or doubt from men of proved trustworthiness.'"[40]

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[38] *Bridges*, 202. Unde oportet primo credulitatem fieri, donec secundo sequitur experientia, ut tertio ratio comitetur. . . . Et ideo in principio debet credere his qui experti sunt, vel qui ab expertis fideliter habuerunt, nec debet reprobare veritatem propter hoc, quod eam ignorat, et quia ad eam non habet argumentum.

[39] *Ibid.*, 219. Postquam enim hoc intuitus sum, nihil fuit meo intellectui difficile ad credendum, dummodo habuit auctorem certum.

Bacon's discussion of experimental science, therefore, on its positive side amounts to little more than a recognition of experience as a criterion of truth and a promulgation of the phrase 'experimental science.'[40a] Let us now look at other writers. Bacon himself, by his copying 'experiments' from other books and by his locating an 'experimenter' even at degenerate scholastic Paris, has suggested that we may find the subject treated elsewhere. We shall not find, it is true, any such express and lengthy discussion of the matter as his, but we may get the same substance in briefer form from the fairly numerous incidental references to experience and experiment.

As for experience as a criterion of truth, as early as the twelfth century we find writers on nature either asserting this or implying it. Early in that century Adelard of Bath in his *Natural Ques-*

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[40] *Ibid.*, 211. Nam certum est quod Æthiopes sapientes venerunt in Italiam et Hispaniam et Franciam et Angliam, et in istas terras Christianorum in quibus sunt dracones boni volantes, et per artem occultam quam habent excitant dracones de cavernis suis, et habent sellas et frœna in promptu, et equitant super eos et agitant in ære volatu fortissimo, ut dometur rigiditas carnium et temperetur durities, sicut apri et ursi et tauri agitantur canibus et variis percussionibus flagellantur, antequam occidantur pro comestione. Cum ergo sic domesticaverint eos, habent artem præparandi carnes eorum, . . . et utuntur eis contra accidentia senectutis, et vitam prolongant et intellectum subtiliant ultra omnem æstimationem. Nam nulla doctrina quæ per hominem fieri potest tantam sapientiam inducere valet sicut esus istarum carnium, secundum quod per homines probatæ fidei didicimus sine mendacio et dubitatione.

[40a] The weak points in Bacon's discussion of experimental science have not hitherto passed wholly unnoticed. Mr. Taylor grants that "even his discussion of experimental science has touches of mediævalism which are peculiarly dissonant in this most original and 'advanced' product of Bacon's genius"; wonders "where the *experimentator* ever observed an eagle or a phœnix renewing its youth, outside of the *Physiologus?*"; and recognizes "how loose must have been the practise or the dreams of his 'experimental science,'" and that "he repeats himself continually in stating its properties and prerogatives, yet without advancing to greater clearness of conception." "His fundamental conception seems to waver: *scientia experimentalis*, is it a science, or is it a means and method universally applicable to all scientific investigation?" (*The Mediæval Mind*, II, 500, 502, 504, 506). And the *Westminster Review* says, "Notwithstanding his forcible language about the prerogatives of experimental science and his bitter invective against frail authority, we find him occasionally resting on authority with childlike faith, and treating his favorite science as if its only prerogative was to provoke a smile." The *Review* then cites some of Roger's absurd 'experiments.' (Vol. 81, p. 241.)

tions attacked exclusive trust in authorities, and, while relying especially upon reason, also adduced experience.[41] Alexander Neckam (1157–1217), who in 1213 was elected Abbot of Cirenchester, in his *De naturis rerum* calls upon "diligent investigators of nature" to testify to the virtues of words, herbs, and stones, which have been demonstrated "by most certain experience."[42] Michael Scot, writing early in the thirteenth century, often uses the word *experimentum* in his elaborate introduction to astrology.[43] So does Vincent of Beauvais later in the century in his huge work on nature, the *Speculum naturale*.[44] The *Thesaurus pauperum* of Peter of Spain, who seems to have become Pope John XXI (died 1277), is further described in its title as, "Or concerning the ills of the human body by experiments ingenious, simple, and particular; an empirical book, from all sorts of authors and my own experience."[45] The scholastic form of the celebrated *Conciliator* of Peter of Abano, composed about 1300 and one of the most elaborate of mediæval medical treatises, makes one scarcely anticipate mention of experience or experiment. Yet Peter couples reason and experience as of equal authority, disagrees with those who deny that medicine is a science because it employs experience as well as reason, and in other passages alludes to his personal astronomical observations and his own successful experimenting with an incantation and an astronomical image.[46]

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[41] Adelardus Bathoniensis, *Quæstiones naturales perdifficiles*, Louvain, 1480, Caps. 16 and 18. The British Museum has two copies of this edition (48 leaves and 30 lines to a page), and one copy of an edition with 43 leaves and 32 lines to the page.

[42] Alexander Neckam, *De naturis rerum*, II, 85, in Vol. 34 of the Rolls Series. Neckam's editor, Thomas Wright, declared that "he not infrequently displays a taste for experimental knowledge."

[43] Michael Scot's *Liber Introductorius* exists in manuscripts at Oxford (Bodleian 266) and at Munich (*Cod. Lat.* 10268).

[44] Vincentius Bellovacensis, *Speculum naturale*, Nurembergæ, Anth. Koburger, 2 folio vols. I found this work at the library of the Union Theological Seminary, New York.

[45] Petrus Hispanus, *Thesaurus pauperum*, seu de medendi humani corporis morbis per experimenta euporista simplicia et particularia; liber empiricus ex omni genere auctorum et experientia propria, Frankfurt, 1578. This and most of the medical works which follow I consulted at the John Crerar Library, Chicago. Peter was really born in Lisbon (*Histoire Littéraire de la France*, Vol. XIX, 322 ff.).

[46] Pietro d'Abano, *Conciliator differentiatum philosophorum et medicorum*, Venice, 1526. Diffs. III, IX, CXIII, and X; or fols. 5, 14, 154, 16 and 15.

A favorite theory in the twelfth and thirteenth centuries is that the things of nature possess 'occult virtues' which cannot be reasoned out but must be learned experimentally. The hypothesis was still in force[47] that all natural objects were composed of only four elements, earth, air, fire, and water, and characterized by four qualities, hot, cold, dry, and moist. It was impossible even by the most ingenious reasoning to explain on this basis certain properties of objects, such as the action of the magnet. So men decided that things possessed occult virtues in addition to the qualities which they derived from their component elements. Many believed that these occult properties were due to the influences of the stars; but in any case all agree that they can only be discovered by experience. General principles and logic give no clue to them. Peter of Abano writes, "We perceive that precious stones and medicines have marvellous and occult virtues which cannot come from the qualities and natures of the elements. . . . Effects of this sort cannot be investigated by reasoning based on the qualities of the elements, but rather by experience."[48] In the same strain write Arnald of Villanova,[49] a medical author who died in 1312, Thomas Aquinas,[50] Albertus Magnus, [51] and others.

Indeed, writers on Albertus Magnus have not failed to notice that his scientific writings are neither mere commentaries upon Aristotle, nor compilations from a variety of sources; but that he both recognizes experience as a criterion of truth, and frequently states the results of his personal observations. This becomes especially evident in the last few books of his treatise on animals where he often states, "I have tested this," or "I and my associates have experienced,"[52] or "I have proved that this is not true," or "I have not experienced this."[53] In treating of whales he limits himself entirely to the results of his own experience, saying, "We pass over the writings of antiquity on this topic because they do not agree with experience."[54] Albert also often expresses doubt as to certain statements concerning animals on the ground that they have not been tested by experience, even if he has had no opportunity to disprove them; and he draws a sharp distinction between authors who state what they themselves have seen or tested, and those who appear simply to repeat rumor or folk-lore.[55] He is particularly chary of accepting the assertions of Solinus and Jorach, assuring us, anent their assertion that certain birds can fly unharmed through flames, "Those philosophers tell many lies and I think that this is one of their lies."[56]

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[47] It of course came down from the classical period.

[48] *Conciliator*, Diff. LX, fol. 83. Conspicimus etiam lapides preciosos et medicinas virtutes mirabiles et occultas habere que ex qualitatibus et naturis non possunt consurgere elementorum. . . . Huiusmodi actiones per rationes a qualitatibus sumptas elementorum investigari non possunt sed per experientiam magis. . . .

[49] See his *Medicinalium Introductionum Speculum*, Cap. 18; *Repetitio super Canon 'Vita brevis*,' fol. 127 in his *Opera* as edited at Lyons, 1532; *De parte operativa*, fol. 276 in his *Opera*, Lyons, 1532. This edition was lent to me by the Harvard University Library.

[50] See his *De occultis operibus naturæ ad quemdam militem*, Vol. 27, pp. 504–7 in Fretté et Maré's edition of his *Opera*, Paris, 1871–1880; *Summa*, secundæ secunda, Quæst. 96, Art. 2.

[51] See his *De mineralibus*, Liber II, Tract. I; *De veget. et plantis*, V, II, 6. I have used Borgnet's edition of Albert's works, Paris, 1890–1899, 38 vols.

On the other hand, Albert accepts as the statements of men of experience the stories which hunters, fowlers, and fishermen have told him. Toward such contemporary personal testimony he is, like Bacon, unduly credulous. He says that "a trustworthy person" told him that he saw in an eagle's nest 300 ducks, over 100 geese, about 40 hares, and many large fish, all of which were required to satisfy the hunger of the young eagles.[57] However, Albert is somewhat less credulous than Bacon on the subject of dragons. That the Æthiopians eat the flesh of dragons to cool themselves, that dragons are afraid of thunder and therefore enchanters imitate the noise of thunder with drums in order to capture dragons and ride on them through space, that a dragon by a coil of its tail can crush an elephant: all these reports Albert treats as rumors rather than tested facts.[58] He also suggests that meteors or flaming vapors have been mistaken for dragons flying through the air and breathing forth fire. He has, however, "heard from trustworthy persons" that a serpent with the virgin countenance of a beardless man "was slain in an island of Germany and there displayed in our times to all who wished to see it until the flesh putrefied."[59] Albert also still states that adamant can be broken only by goat's blood, an error which Bacon rejects.[60] On the other hand, one notion which Bacon himself attacks but which he represents as generally accepted, namely, that the beaver when hunted castrates itself to save its life, Albert also rejects, saying that experience near his home has often proved the contrary.[61] Again, Bacon tells how he himself has profitted by an 'experiment' which the magicians pretend to perform by virtue of an incantation. The experiment consists in holding the split halves of a hazel rod apart at the two ends, whereupon the middle portions bend toward each other. Bacon says, "I omitted the incantation and discovered a marvel of nature."[62] But Albert and also John of St. Amand, a medical writer about 1261, both narrate this same marvel of nature and assure us that it works without the incantation.[63]

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[52] *De animalibus*, 22, 2, 10; 22, 2, 99; 23, 1, 83; 23, 1, 5; 23, 1, 34; 23, 1, 35; 24, 1, 123, sicut olim in hac scientia probavimus; 26, 1, 10, experti sumus ego et socii mei; 26, 1, 14; 26, 1, 20.

[53] *Ibid.*, 23, 1, 23, experimento probavimus falsum esse; 23, 1, 57, probavi in quibusdam verum non esse; 23, 1, 9; 23, 1, 83; 23, 1, 14; 23, 1, 104.

[54] *Ibid.*, 24, 1, 28. Hæc sunt quæ de cetorum natura nos experti sumus, et ea quæ scribunt Antiqui præterimus quoniam non concordant cum expertis.

[55] *Ibid.*, 23, 1, 40, caps. 18, 20, 21; 25, Introd.; 23, 1, 54, Gryphes aves esse magis tradunt historiæ quam experta Philosophorum vel rationes philosophiæ; 23, 1, 93, Hæc autem potius in historiis leguntur quam sint experimento per philosophiam probata; 23, 1, 101; 26, 1, 47, Sed hoc licet sit famosum tamen a rumore vulgi potius acceptum est quam certo experimento probatum sit.

[56] *Ibid.*, 23, 1, 22. Sed illi philosophi multa mentiuntur et puto quod hoc sit unum de mendaciis eorum. See also 22, 2, 56, Sed iste Jorach frequenter mentitur; 25, 1, 5, Et sicut in multis mentitur Solinus ita et in hoc falsum dicit; 23, 1, 55. Statements by Pliny the Elder are rejected by Albert in 23, 1, 9; 25, 1, 13; 25, 1, 26.

[57] *Ibid.*, 23, 1, 9; also 22, 2, 19, and 24, Introd.

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[58] *Loc. cit.*, 25, 1, 26.

[59] *Ibid.*, 25, 1, 28. Talem serpentem a fide dignis audivi interfectum esse in insula Germaniæ et diu monstratum nostris temporibus omnibus volentibus eum videre donec computruit.

[60] Albertus Magnus, *De mineralibus*, II, ii, 1.

[61] *De animalibus*, 22, 2, 1, 21; and Bridges, II, 168–9. See further Pouchet, 285–6.

[62] *Bridges*, II, 219. Et ego neglexi carmina et inveni opus naturæ mirabile.

[63] *De veget. et plantis*, VI, i, 29; John of St. Amand, *Expositio in Antidotarium Nicolai*, fol. 268 in *Mesuæ medici clarissimi opera*, Venice, 1568. John, however, states that the witches do not assert that their incantations make the sticks bend toward each other, but that the incantations prevent the rods from joining in case the marriage concerning which the witch is consulted is one destined to result unhappily.

It is true that Albert's allusions to experience occur mainly when he is discussing the specific properties of particular things. In his treatise on animals we find such allusions in the books where he is listing and describing particular animals, rather than where he discusses the general natures and common characteristics of animals. This is true again in his treatise *On Vegetables and Plants* where allusions to experience occur especially in the sixth book, in which particular plants are listed and described and, as Albert says, "We satisfy the curiosity of our students rather than philosophy, for philosophy cannot deal with particulars."[64] However, in his *Physics* Albert states that "every hypothesis which is confirmed by the senses is better than that which contradicts sense; and a conclusion contrary to sense is incredible: indeed, a principle which does not agree with *experimental knowledge* acquired by the senses is no principle but quite the opposite."[65]

Other authors than Bacon not only rely on experience, they also mention 'experimenters' and cite experimental books or 'books of experiments.' In short, others than he have conceived the possibility of purposive experimentation, although we find their ideas as to experimental method in the same crude state as his. Bernard Silvestris, a teacher at Tours in the first half of the twelfth century, entitled an astronomical treatise which he composed *Experimentarius*.[66] Early in the thirteenth century Thomas of Cantimpré, in the preface to his *De naturis rerum*, cites "a certain book without name of author which I have heard was compiled in modern times, whose statements you will know wherever you meet them from this indication, that you will find the name *Experimentator* (experimenter) prefixed."[67]

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[64] *De veget. et plantis*, VI, i, 1. In hoc sexto libro Vegetabilium nostrorum magis satisfacimus curiositati studentium quam philosophiæ, de particularibus enim philosophia esse non poterit.

[65] *Physic.*, VIII, ii, 2. Omnis autem acceptio quæ firmatur a sensu, melior est quam illa quæ sensui contradicit; et conclusio quæ sensui contradicit est incredibilis: principium autem quod experimentali cognitioni in sensu non concordat, non est principium, sed potius contrarium principio.

[66] Clerval, *Les Écoles de Chartres*, Chartres, 1895, p. 240.

[67] Cited by the *Histoire Littéraire de la France*, Vol. 30, pp. 371–2. Invenies etiam librum quemdam suppresso auctoris nomine quem modernis temporibus compilatum audivi, cuius sententiæ ubique repereris ex hoc cognosces quod hoc nomen 'Experimentator' subsequentibus invenies prælibatum.

The *Speculum astronomiæ*, a treatise probably written by Albertus Magnus, mentions a *Book of Experiments* by the Arab Albumasar;[68] Arnald of Villanova attributes a book of experiments to another Arab, Rasis.[69] Bernard Gordon cites the opinions of "experimenters" in his *Lilium medicinæ* which he began to write in 1303.[70]

As Bacon's experimental scientist was "ashamed to have some layman or old-wife or knight or rustic know facts of which he is ignorant," so Arnald of Villanova admits that the practical man of experience may know more of nature than the bookish scholar. "For since the properties of things cannot be discovered by reason but only by experiment or revelation, and experience and revelation are common to the ordinary man and to the scholar, it is possible that knowledge of properties may be attained by the common people sooner than by others."[71] Arnald not only speaks of "experimenters" but of a "philosopher and experimenter"[72]; and in another treatise states that a certain hypothesis "can be satisfactorily proved by the long experience of any intelligent operator."[73] He also speaks of "rational experiment" which "always presupposes a determined object."[74]

John of St. Amand asserts that *experimentum* alone is "timorous and fallacious," but that "fortified by reason" it gives "experimental knowledge." His idea seems to be, not only that experience must be combined with theory, but also that there should be methodical experimentation. He gives seven rules to be observed in discovering experimentally the properties of medicinal simples: that the simple tested should be pure and free from every extraneous quality, that it should be tested in a simple and not a complex disease, that several tests be made, that the dose administered should be proportioned to the patient's constitution, and so on.[75]

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[68] *Speculum astronomiæ*, Cap. 7.

[69] *Opera*, Lyons, 1532, fol. 276.

[70] Bernard Gordon, *Lilium medicinæ*, Venice, 1496, fol. 159 (Pars V, Cap. 12).

[71] From his *Repetitio* super Canon 'Vita brevis,' Opera, Lyons, 1532, fol. 276. Nam cum notitiam proprietatum non possit haberi per rationem sed tum experimento vel revelatione, et experientia et revelationes sunt communes vulgo et sapientibus, possibile est ut proprietatum notitiæ prius habeantur a vulgaribus quam ab aliis.

[72] *Regimen podagræ*, fol. 210–211 in the *Opera*.

[73] *Regulæ generales curationis morborum*, Doctrina IV. Quod potest valde bene haberi per experientiam longam cuicunque operanti et intelligenti.

[74] *Medicinalium Introductionum Speculum*, Cap. 19. Rationabile enim experimentum semper præsupponit determinatum obiectum.

On the whole one rather gets the impression that the experimental method which Bacon pleads for, as if it were a novelty, is calmly assumed by other writers as a well-established method. It is even doubtful if Roger can be credited with having coined a new phrase in 'experimental science,'[75a] since not only do others employ the adjective 'experimental' and the noun 'experimenter,' but both Albertus Magnus and John of St. Amand use the expression 'experimental knowledge.'

It is significant that others not only duplicate Bacon's positive contributions, but that their experimental method is characterized by precisely the same failings as his. They display the same credulity and love of the marvelous, and are especially prone to mention experiment when they wish to prove something unreasonable, and to support incredible assertions by assurances that they have been tested by experience. They show the same inclination to fantastic 'experiments.' What Arnald's "experimenters" have proved is that a frog's legs bound to the patient's feet for three days, with the right leg on the right foot and the left leg on the left foot, cure gout. What his "philosopher and experimenter" has demonstrated is that application of the magnet has the same effect. To Socrates Arnald attributes this "marvellous and choice experiment." "In young swallows are found two stones, one red and one white. Application of the white stone will raise up a falling lunatic; and the red stone will benefit him, if tied in a bit of skin about his neck."[76] Albert matches Bacon's snake experiment by one with a toad and emerald, which he tells to illustrate "the many effects of stones and plants that are known by experience and by which wonders are worked."

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[75] *Expositio in Antidotarium Nicolai*, fol. 231 in *Mesuæ medici clarissimi opera*, Venice, 1568.

[75a] Sebastian Vogl, *Die Physik Roger Bacos*, Erlangen, 1906, p. 17, says of *scientia experimentalis*, "Diese Bezeichnung tritt in seinem Werken zum erstenmal auf und verschwindet von da ab nicht mehr." Franz Strunz, *Geschichte der Naturwissenschaften im Mittelalter*, Stuttgart, 1910, 120 pp. (no references), also says of *scientia experimentalis*, "Das Wort steht hier bei diesem Gelehrten das erstenmal" (p. 97).

[76] *De epilepsia* (fol. 311 ff. in the *Opera*), Cap. 4. Socrates vero recitat hoc experimentum pro mirabili et electo: in pullis inquit irundinum inveniuntur duo lapides quorum unus est rubens, alter est albus; albus quidem lunatico cadente appositus levabit eum; rubens autem acceptus et ligatus in pelle collo ei apponitur.

"An emerald was recently seen among us, small in size but marvelous in beauty. When its virtue was to be tested, someone stepped forth and said that, if a circle was made about a toad with the emerald and then the stone was set before the toad's eyes, one of two things would happen. Either the stone, if of weak virtue, would be broken by the gaze of the toad; or the toad would burst, if the stone was possessed of full natural vigor. Without delay things were arranged as he bade; and after a short lapse of time, during which the toad kept its eye unswervingly upon the gem, the latter began to crack like a nut and a portion of it flew from the ring. Then the toad, which had stood immovable hitherto, withdrew as if it had been freed from the influence of the gem."[77]

The following experiment with a religious tinge was a favorite with medical writers. I quote John of Gaddesden's version.

"Since many boys and others who cannot take medicine are troubled with epilepsy, let the experiment be performed which Constantinus gives in the chapter on epilepsy in the fifth book of his *Practica*, and Walter in his *Practica*, and Bernard, and Gilbert, and everyone. And I have found it true, whether the patient be a demoniac, or epileptic, or lunatic. If he has a father and mother, let them take him to church after fasting with him for three days, and let him make confession, provided he has reached years of discretion. Then let them go on Friday in the fast of four seasons and hear mass, and let them repeat this on Saturday. On Sunday let a good religious priest read in church over the patient's head the Gospel which he reads in

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[77] *De veget. et plantis*, VI, ii, 1. Smaragdus enim nuper apud nos visus est parvus quidem quantitate et mirabiliter pulcher, cuius cum virtus probari deberet, adstitit qui diceret, quod si circa bufonem circulus smaragdo fieret et postea lapis oculis bufonis exhiberetur, alterum duorum, quod aut lapis frangeretur ad visum bufonis si debilem haberet lapis virtutem, aut bufo rumperetur si lapis esset in naturali suo vigore: nec mora factum est ut dixit et ad modicum temporis intervallum, dum bufo adspiceret lapidem nec visum averteret ab ipso, crepitare coepit lapis sicut avellana rumperetur et exilivit ex annulo una pars eiusdem, et tunc bufo qui ante stetit immobilis, cœpit recedere ac si absolutus esset a lapidis virtute.

September after the harvest feast of the holy cross in the days of the four seasons. Moreover, let him devoutly write the same, and let the patient wear it about his neck and he will be cured. The Gospel meant is the passage, 'This kind of demon is not cast out except by fasting and prayer.'"[78] Many more such 'experiments' might be given.

In reality, therefore, Bacon's discussion of experimental science, instead of being a wonderful original contribution to knowledge, is an excellent representation of both the good and bad points of an important movement of the time in the direction of experimental method. Crude as this tendency may be, it at least demonstrates that the interests of the period were not exclusively scholastic.

Two further questions concerning experimental method in the middle ages suggest themselves. Was there any positive advance in this respect over the science of the classical period? How are we to explain the association of so much superstition with experimental method?

To the former question I incline to answer, Yes. Pliny the Elder, whose *Natural History* (written in the first century of our era) was a compilation of all previous science, should know of experimentation if it had ever amounted to much hitherto. He frequently uses the word *experimentum* but seldom in such a way that it is best translated 'experiment.'[79] He never uses the words 'experimental' and 'experimenter', which are post-classical. Several of our mediæval writers cite Galen as an authority for the recognition of experience as a criterion of truth.[80] It is true that Galen, writing a century later than Pliny and showing an advance in anatomical and medical knowledge over his predecessors, approaches more closely the conception of experimental method. He himself engaged in original research in anatomy, dissecting and vivisecting, and proving by actual experiment that the arteries contain blood, not air.[81] It is true, as John of St. Amand and Peter of Abano state, that Galen makes both reason and experience criteria of truth in medicine;

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[78] John of Gaddesden, *Rosa medicinæ* (written in the early fourteenth century). Papiæ, 1492 (Joannes antonius birreta impressioni tradidit). Et cum multi pueri et alii qui non possunt uti medicinis vexantur epilepsia, fiat experimentum quod ponit Constantinus 5 practicæ suæ c. de epilepsia, et Gualterius in practica sua et Bernardus et Gilbertus et omnes. Et ego inveni illud verum sive sit demoniacus sive lunaticus sive epilepticus. Si patrem habet et matrem, ducant eum ad ecclesiam facto jejunio trium dierum a parentibus et a patiente, si sit tantæ ætatis quod sit compos sui, et confiteatur. Deinde vadant die veneris in jejunio quatuor temporum et audiant missam de die et similiter in die sabbati. Die dominica sequenti sacerdos bonus religiosus legat supra caput patientis in ecclesia evangelium quod legit in septembri tempore vindemiarium post festum sanctæ crucis in diebus quatuor temporum. Tunc etiam scribat illud idem devote et portat circa collum et curatur; et est evangelium ubi dicitur, Hoc genus demonii non ejicitur nisi in jejunio et oratione. The same recipe occurs in Bernard Gordon's *Lilium medicinæ*, Partic. II, Cap. 25, fol. 76.

[79] Often it simply means experience, as in the passage, "Let him marvel at this who has not observed by daily experience that the herb called heliotrope always

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turns toward the sun." II, 41, 2 (Edition by Lemaire, Paris, 1827): see also, II, 41, 1; II, 108, 1; VII, 41, 2; VII, 56, 3; XIV, 8, 2; XVI, 1, 3; XVII, 2, 3, and 12; XVII, 35, 9; XX, 52, 1; XXII, 51, 2; XXIII, 59, 1; XXV, 106, 2. Again it may be rendered as "example" or "actual instance," as when Pliny says, "We have instances (experimenta) and examples (exempla) in the last census" of men who have lived over 120 years. VII, 50, 3; also, II, 54, 2; VIII, 7, 2; IX, 86, 1; XXII, 49, 5; XXVIII, 45, 2. Or it may mean use, as in the passage, "Reeds useful in both war and peace," or where it is stated that most plants "have been recommended for frequent use by their edibility or odor or beauty," XVI, 64, 1; and XXII, 1, 1. When Pliny tells that Claudia was shown to be chaste by a religious ordeal, the phrase used is, "religionis experimento," VII, 35, 1. Often the word means 'test,' as when Pliny discusses ways of testing the genuineness of gems, the freshness of eggs, and the realism of paintings: see V, 1, 12; X, 75, 1; XIII, 3, 1; XIV, 25, 7; XVII, 4, 2; XX, 3, 1; XX, 76, 5; XXII, 23, 1; XXIII, 31, 1; XXVIII, 7, 2; XXIX, 12, 1; XXXI, 27, 2; XXXI, 28, 2; XXXIII, 19, 2, and 43, 1, and 44, 1, and 57, 2; XXXIV, 26, 3, and 39, 2; XXXV, 36, 2; XXXVI, 38, 1, and 55, 2; XXXVII, 22, 1, and 76, 1–2. Purposive action is clearly suggested in only a few cases: namely, where Pliny says that experiments cannot entirely duplicate nature in the grafting of trees; where he describes as an experiment the marking of a dolphin's tail in order to learn the dolphin's age, if it should be caught again; where a well was sunk to prove that the sun casts no shadow at noon of the summer solstice; and where a man was cast into a pit of serpents at Rome to discover if he really was immune from them. XVII, 26, 3; IX, 7, 2; II, 75, 1; XXVIII, 6, 1; and perhaps, XXVIII, 14, 3; XXIX, 4, 1, and 8, 3.

Of course, in the middle ages, too, the word 'experimentum' does not always carry the meaning of experiment. It may indicate experience, or be used of the results of experience. Recipes as well as procedures, often mere lists of ingredients which are to be tried or are supposed to have been successfully tested as remedies against various diseases, are often called 'experimenta' by medical writers. Thus Bernard Gordon gives nine 'experimenta' for eye troubles. *Lilium medicinæ*, Partic. III, Cap. 5, fol. 94.

[80] Pietro d'Abano, *Conciliator*, Diff. X, fol. 15; Diff. LX, fol. 83. Jean de Saint-Amand, *Expositio in Antidotarium Nicolai*, fol. 231. Arnald of Villanova, *Repetitio super Canon 'Vita brevis,'* fol. 276.

[81] See Vol. II, pp. 642 and 646–649; IV, 703–36 in Kuhn's edition of Galen.

but as he insists that they ought not to be employed simultaneously, he misses the essence of experimental method. He further objects that experience is unscientific, irrational, and that it "requires good fortune to find what is sought." Once he identifies it with mere observation.[82] The Empirics were the chief advocates of experience in the ancient medical world, and Galen broaches the topic mainly in connection with allusions to their sect. He usually depicts them as over-emphasizing experience and neglecting reason, as regarding phenomena only and ignoring causes, as learning what drugs to use from dreams and chance, and as trusting unquestioningly in authorities and tradition for information concerning the experience of past ages.[83] The Empirics themselves insisted that experience was a scientific method.[84] They distinguished three kinds, of which Galen unfortunately gives no further description, namely, accidental, off-hand, and imitative.[85] They held that observation of a single instance was not enough, but that repeated observation with things remaining in the same condition was necessary.[86] Thus they seem both to have had some of the faults of our mediæval scientists and to have had at least some notion of controlling the results of experience. Indeed, Galen himself believes that the properties of medicinal simples can and should be learned from experience, and gives some rules for testing their effects from which John of St. Amand seems to have developed his longer directions.[87] Admitting, however, the debt of the middle ages to Galen, it seems true that they rely more frequently on experience than the ancients did; that they apply it more generally through the field of science, rather than merely to medicinal simples as Galen did, or to medical practise as the Empirics did; that they have developed the theory of occult virtues which can be discovered only by experience; that they have 'experiments' and 'experimenters' and entire books called experimental. Others besides Bacon seem conscious that science is finding a new method in their day, and Peter of Spain, in stating his sources of information, speaks of "ancient philosophers" but of "modern experimenters."[88]

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[82] Kuhn, X, 28–31: also I, 131 and 138; XIV, 675–6.

[83] Kuhn, XIV, 220 and 245, 679–680; I, 143; also XVI, 82; I, 76 and 134.

[84] Kuhn, I, 76.

[85] Kuhn, XVI, 82.

[86] Kuhn, I, 135.

[87] Kuhn, XVI, 85–87; XI, 485 and 518.

As for the other matter, the credulity, the superstition, the element of marvelousness, which seem to vitiate the experimental tendencies of Bacon and his contemporaries,—these are to be explained as the result of a real connection between experiment and magic. There is abundant evidence for this. Bacon, it is true, asserts that experimental science exposes and shuns all the follies of the magicians, but he admits that many persons confuse it with magic because of the marvels which it works, and he himself especially associates it with the occult sciences of alchemy and astrology. It makes gold such as neither the art of alchemy nor nature can produce; it can predict the future better than astrology.[89] It teaches one to choose the proper constellations for his undertakings, and to use the right words at the proper times;[90] it can construct "philosophical images and incantations and characters" which are vastly superior to those of magic;[91] it can alter the world about us, and incline and excite the human will, though without coercion.[92] Moreover, Bacon's ideal experimental scientist does not scorn to take hints from wizards, while Roger himself derives his hazel rod experiment from the magicians. The snake experiment of his sage at Paris sounds more like the trick of a Hindu conjurer than the procedure of a modern laboratory.

One gets the same impression from Bacon's contemporaries. The conception of occult virtue, which leads them so often to rely on experience, is a more or less magical notion, akin to the *mana* of primitive magic.[93] Believers in astrology, divination, and fascination also appeal to experience. Vincent of Beauvais says that divination from portents is proved by many experiences, and that the influences of the planets upon our world were discovered by philosophers by "sure experiments" as well as by "convincing arguments."[94] Albertus Magnus assures the reader that divination from dreams is "no idle report but the testimony of experience."[95] In another treatise which has sometimes been attributed to Albert we read, "When the soul of any person is raised to great excess of some passion, it is found by manifest experiment that it binds and alters objects as it wishes."[96] The experiments of Bacon's contemporaries, too, are often more like feats of magic than like scientific tests. Gaddesden's experiment employed an incantation and amulet. Peter of Abano experimented with an incantation and an astronomical image; and a necromantic book attributed to him bears the sub-title, "A book of marvellous experiments."[97] Michael Scot describes "a chiromantic experiment," and mentions "love experiments" and the experiments of necromancers and magicians.[98] Arnald recounts an "experiment" performed by an old-wife of Salerno to help women in childbirth. It consisted in taking three grains of pepper; saying a Lord's Prayer over each with substitution of the sentence, "Deliver this woman from the pangs of childbirth," for the words, "Deliver us from evil"; giving the grains one by one to the woman to be swallowed in wine or water without touching the teeth; and finally uttering this incantation with three Paternosters in her right ear,

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[88] Petrus Hispanus, *Thesaurus pauperum*, Frankfurt, 1578, Preface. In libris antiquorum philosophorum et modernorum experimentatorum.

[89] *Little*, 46; *Gasquet*, 510.

[90] *Little*, 52.

[91] *Ibid.* 53.

[92] *Gasquet*, 510. Opera vero istius scientie quedam naturalia sunt in alteratione mundi, quedam in excitationem et inclinationem voluntatum sine coactione.

[93] For "L'idée de *mana*" see H. Hubert et M. Mauss, "Esquisse d'une Théorie Générale de la Magie," *L'Année Sociologique*, 1902–03, pp. 1–146, especially 109 ff.

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[94] *Speculum naturale*, XXXII, 119; XVI, 43.

[95] *De somno et vigilia*, III, i, 2. Est enim hoc non auditus inanis sed experientiæ testimonium.

[96] *De mirabilibus mundi*, p. 159 in an edition of Amsterdam, 1740 (Columbia University Library), where it is bound with the *De secretis mulierum*. These works are omitted from Borgnet's edition, but there are no very convincing reasons for doubting Albert's authorship. The passage reads, "Cum igitur anima alicuius fertur in grandem excessum alicuius passionis, invenitur experimento manifesto quod ipsa ligat res et alterat ad idem quod desiderat."

[97] *Heptameron seu elementa magica;* bound with the *Opera* of H. C. Agrippa Lyons, 1600, pp. 441–462 (Cornell University Library).

[98] *De secretis naturæ* (a portion of Scot's long work on astrology which is printed in the edition of Amsterdam, 1740, mentioned in note 96), Cap. 18, In chiromantia est illud experimentum, etc. Bodleian ms. 266, fol. 22 v. quotiens nigromantici vel magi volunt experimentorum aliqua operari veraciter; and fol. 106 r. hec stella est multe efficacie ad experimenta amoris.

> Bizomie lamion lamium azerai vachina deus deus sabaoth
> Benedictus qui venit in nomine domini osanna in excelsis.

Arnald condemns this procedure as diabolical and contrary to the Faith, but he calls it an experiment nevertheless; and earlier in the same treatise describes approvingly a very similar experiment by which a priest cured him of warts.[99] Albert concludes his tale of the toad and the emerald by stating that there are many other effects of stones and herbs, which we learn by experiment, and which magicians study, and work wonders by means of them.[100] In the *Speculum astronomiæ* he calls "experimental books" those which deal with different varieties of divination, namely, aeromancy, pyromancy, hydromancy, geomancy, and chiromancy; and he declares that such books ought not to be called science, [101] which recalls Bacon's remark that to some men experimental science seems false and unworthy of a Christian. In a treatise entitled *Apollonii Flores aurei*,[102] which treats of the Notory Art of miraculous acquisition of knowledge by incantations and invocation of spirits, experiments and experimental science are again mentioned in the same breath with the above named varieties of divination. Books "which are nigromantic or contain the experiments of lot-casters" were condemned at Paris in 1277 together with the opinions of Siger de Brabant.[103]

This is not the place to discuss magic, but from further investigation which I have made of its history and its relations to science[104] I have little doubt that the connection between it and experimentation which our authors suggest is real. But this is not so much to the discredit of science as it is to the credit of magic. After all it is not surprising that magic, which was curious and tried to do things and to attain practical results, and which as long ago at least as Pliny the Elder's day had investigated nature,[105] should experiment. It is indeed possible that magicians were the first to experiment, and that science, originally speculative, took over experimental method, as well as the conception of occult virtue, from magic.

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[99] *Breviarium* (fols. 150–205 of the *Opera*), III, 4; and II, 45.

[100] *De veget. et plantis*, VI, 11, 1. Sunt autem multi alii effectus lapidum et plantarum qui experimento accipiuntur in eosdem in quibus student magici et mira per eos operantur.

[101] *Speculum astronomiæ*, Cap. 17.

[102] This treatise is contained in two manuscripts of the fourteenth century at Munich, *Cod. Lat.* 268 and 276. See fols. 5–6 of the latter.

[103] Denifle et Chatelain, *Chartularium Universitatis Parisiensis*, I, 543. Libros, rotulos, seu quaternos nigromanticos aut continentes experimenta sortilegiorum.

[104] Lynn Thorndike, *The Place of Magic in the Intellectual History of Europe;* New York, 1905. "The Attitude of Origen and Augustine to Magic," *The Monist*, XVIII, 46–66 (January, 1908). "Julius Firmicus Maternus, A Roman Astrologer as a Historical Source," *Classical Philology*, VIII, 415–435 (October, 1913). An article on "Some Mediæval Conceptions of Magic" will soon appear in *The Monist.*

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[105] The *magi* stand out in the pages of Pliny's *Historia naturalis*, not as mere sorcerers or enchanters, but as those who have gone farthest and in most detail,—too curiously, in Pliny's opinion—into the study of nature.